

# Family Clustering of PBB and DDE Values among Michigan Dairy Farmers

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Family clustering of varying levels of serum PBB and DDE was evaluated for 62 Michigan families by using the mean and standard deviation for family units, ranked percentile comparison of family members, and correlation by linear regression of family members.

The results indicate that levels of serum PBBs cluster within family units and for children within families. Serum DDE clustering within families occurs only for children. These findings are consistent with recent, interim PBB exposure, perhaps from a common dietary source for families. Serum DDE represents a lifetime, low-level exposure to DDT-DDE which has been both less prolonged and less intense for children. Thus similar levels, or clustered serum DDE, was observed for children within families.

PBB contamination of dairy farms in Michigan occurred as an episode of relatively short duration, primarily since 1973. The major route of exposure to PBB was probably by ingestion of contaminated food and indeed, significantly different serum PBB values have been found among dairy farm residents of quarantined and nonquarantined farms (1). Presumably, animal food sources from quarantined farms would tend to represent a more concentrated exposure source. Thus, members of family units tending to have common dietary sources of PBB, would be expected to have had similar exposures.

We have observed an apparent family clustering of serum PBB levels, which generally fall within a limited range for a family. Observations are described for 62 families studied during a survey of Michigan dairy farmers in November 1976 (2). Of interest in this regard is the fact that, during this survey, farm residents were invited to participate as family units [all dwellers on particular farms, or all members of families which purchased food from the farms ("consumers"). The number of family members, of course, varied in the family units studied.]

Davies et al. (3) have reported clustering of DDE concentrations in blood among children within a family. Serum DDE [1,1-dichloro-2,2-bis(*p*-chlorophenyl)ethylene] has been shown to correlate with

age (1, 4), reflecting cumulative lifetime exposure to DDT-DDE, so that clustering of serum DDE in children reflects the relatively short duration of exposure, compared with that of older persons and thus would have a more limited range of values. Since serum DDE levels were studied in the families examined by us, family clustering of DDE has also been evaluated.

## Materials and Methods

Techniques used for serum PBB and DDE analysis are described elsewhere (1). Among the determinations completed at the present time were 62 family units as described above. These family units are analyzed in three separate ways. Serum PBB and DDE were reported as mean and standard deviation for each unit, regardless of family relationships (Table 1). Of these, 24 family units, with three or more children were included in study of family vs. children clustering (Tables 2 and 3), and 60 families were selected for ranked, mean and intrafamily individual correlation analysis (Table 4). These latter family units were limited to two-parent families with one or more children residing in the same household.

## Results

Mean serum PBB values, depicted in Table 1 and ranked graphically (Figs. 1 and 2) ranged lower for family groups resident on nonquarantined farms

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than for quarantined farm families. Family clustering of serum PBB is suggested by the standard deviation from the mean family value, which tended to fall within a limited range such that the highest values did not overlap lower values. The large standard deviation for high mean PBB represents a range of individual serum PBB within the same order of magnitude. For example, the mean  $\pm$  SD (732  $\pm$  653) represents five serum PBB levels: 202, 358, 360, 962, 1778 ppb.

Mean family serum DDE was similar for quarantined and nonquarantined farm families. No correlation was observed for DDE with PBB for intrafamily values, for all family means, or for ranked means (Spearman coefficient).

Family clustering of serum PBB and DDE was evaluated initially by using family mean and stan-

dard deviation. For nonquarantined farm families the standard deviation was less than the mean for PBB and DDE in 22/23 and 20/23 families, respectively (Table 1). For quarantined farm families, the standard deviation was less than the mean for PBB and DDE in 33/39 and 35/39 families, respectively. Using a criterion of standard deviation within the mean to assess clustering, serum PBB and DDE cluster similarly.

To evaluate clustering among children within a family, the mean and standard deviation of the children was compared with those of the family for 24 families with 3 or more children (Table 2). For both PBB and DDE, the standard deviation for children was generally lower than for the entire family. For DDE, among 24 families there were no standard deviations with 30% or 1 ppb of the mean, whereas

Table 1. Mean serum PBB and DDE concentrations for family units.<sup>a</sup>

| n <sup>b</sup> | Quarantined farms |                 | n <sup>b</sup> | Nonquarantined farms |                 |
|----------------|-------------------|-----------------|----------------|----------------------|-----------------|
|                | PBB, ppb          | DDE, ppb        |                | PBB, ppb             | DDE, ppb        |
| 5              | 0.8 $\pm$ 3.0     | 8.2 $\pm$ 4.7   | 4              | 0.4 $\pm$ 0.4        | 9.6 $\pm$ 11.0  |
| 3              | 1.1 $\pm$ 7.0     | 10.7 $\pm$ 9.4  | 3              | 0.5 $\pm$ 0.1        | 17.3 $\pm$ 16.1 |
| 3              | 1.2 $\pm$ 5.0     | 7.5 $\pm$ 4.5   | 4              | 0.6 $\pm$ 0.2        | 9.2 $\pm$ 7.0   |
| 3              | 1.3 $\pm$ 6.0     | 12.0 $\pm$ 6.0  | 9              | 0.7 $\pm$ 0.3        | 8.6 $\pm$ 4.4   |
| 5              | 1.3 $\pm$ 1.0     | 6.1 $\pm$ 4.2   | 6              | 0.9 $\pm$ 0.5        | 4.9 $\pm$ 4.3   |
| 10             | 1.6 $\pm$ 1.0     | 10.6 $\pm$ 8.3  | 6              | 1.0 $\pm$ 0.5        | 27.0 $\pm$ 15.0 |
| 5              | 1.8 $\pm$ 0.6     | 9.8 $\pm$ 7.6   | 5              | 1.1 $\pm$ 0.3        | 16.5 $\pm$ 14.0 |
| 3              | 1.8 $\pm$ 1.0     | 15.2 $\pm$ 12.0 | 4              | 1.1 $\pm$ 0.6        | 9.4 $\pm$ 5.7   |
| 5              | 1.9 $\pm$ 0.7     | 13.5 $\pm$ 7.0  | 5              | 1.1 $\pm$ 0.7        | 5.3 $\pm$ 2.1   |
| 5              | 1.9 $\pm$ 1.6     | 9.9 $\pm$ 6.9   | 6              | 1.2 $\pm$ 0.7        | 8.7 $\pm$ 6.0   |
| 4              | 2.1 $\pm$ 1.5     | 12.8 $\pm$ 11.7 | 5              | 1.4 $\pm$ 0.9        | 11.0 $\pm$ 5.0  |
| 6              | 2.3 $\pm$ 2.0     | 8.9 $\pm$ 5.5   | 3              | 1.6 $\pm$ 0.7        | 12.1 $\pm$ 11.6 |
| 5              | 2.4 $\pm$ 3.3     | 5.3 $\pm$ 2.7   | 5              | 1.9 $\pm$ 1.1        | 12.4 $\pm$ 12.0 |
| 5              | 2.9 $\pm$ 1.0     | 14.6 $\pm$ 9.4  | 7              | 2.2 $\pm$ 1.5        | 12.9 $\pm$ 7.2  |
| 7              | 3.6 $\pm$ 2.2     | 6.5 $\pm$ 4.1   | 4              | 2.5 $\pm$ 0.3        | 15.0 $\pm$ 11.0 |
| 3              | 3.6 $\pm$ 2.9     | 9.9 $\pm$ 6.3   | 4              | 2.8 $\pm$ 1.0        | 4.1 $\pm$ 4.0   |
| 4              | 3.7 $\pm$ 4.0     | 31.3 $\pm$ 16.6 | 5              | 2.9 $\pm$ 5.0        | 10.0 $\pm$ 11.0 |
| 3              | 4.9 $\pm$ 3.5     | 11.4 $\pm$ 2.9  | 8              | 3.0 $\pm$ 1.1        | 8.2 $\pm$ 4.6   |
| 5              | 5.4 $\pm$ 3.0     | 11.1 $\pm$ 10.0 | 5              | 3.2 $\pm$ 2.0        | 12.4 $\pm$ 13.0 |
| 7              | 6.2 $\pm$ 4.2     | 16.6 $\pm$ 7.0  | 6              | 3.9 $\pm$ 1.9        | 11.5 $\pm$ 4.2  |
| 4              | 6.3 $\pm$ 2.7     | 9.7 $\pm$ 5.4   | 3              | 5.6 $\pm$ 4.6        | 18.1 $\pm$ 5.3  |
| 3              | 7.2 $\pm$ 3.9     | 6.5 $\pm$ 3.6   | 7              | 6.3 $\pm$ 5.0        | 5.4 $\pm$ 4.0   |
| 4              | 7.3 $\pm$ 3.6     | 7.9 $\pm$ 2.9   | 5              | 26.0 $\pm$ 16.0      | 4.0 $\pm$ 3.0   |
| 8              | 7.5 $\pm$ 3.4     | 9.6 $\pm$ 6.2   |                |                      |                 |
| 3              | 8.5 $\pm$ 5.7     | 6.1 $\pm$ 4.2   |                |                      |                 |
| 5              | 10.6 $\pm$ 5.0    | 29.6 $\pm$ 39.7 |                |                      |                 |
| 9              | 12.3 $\pm$ 8.3    | 12.3 $\pm$ 4.8  |                |                      |                 |
| 4              | 12.5 $\pm$ 7.5    | 10.0 $\pm$ 3.0  |                |                      |                 |
| 6              | 13.6 $\pm$ 9.2    | 23.8 $\pm$ 29.1 |                |                      |                 |
| 4              | 14.3 $\pm$ 7.0    | 7.8 $\pm$ 3.0   |                |                      |                 |
| 5              | 17.5 $\pm$ 7.8    | 9.5 $\pm$ 6.2   |                |                      |                 |
| 8              | 17.9 $\pm$ 10.4   | 11.5 $\pm$ 14.1 |                |                      |                 |
| 5              | 18.3 $\pm$ 13.2   | 18.3 $\pm$ 13.3 |                |                      |                 |
| 6              | 18.3 $\pm$ 15.4   | 17.7 $\pm$ 13.2 |                |                      |                 |
| 5              | 20.3 $\pm$ 13.6   | 9.8 $\pm$ 7.6   |                |                      |                 |
| 8              | 43.3 $\pm$ 24.3   | 14.4 $\pm$ 2.1  |                |                      |                 |
| 3              | 378.0 $\pm$ 325.0 | 16.1 $\pm$ 11.4 |                |                      |                 |
| 6              | 486.0 $\pm$ 365.0 | 5.1 $\pm$ 3.5   |                |                      |                 |
| 5              | 732.0 $\pm$ 653.0 | 30.4 $\pm$ 51.7 |                |                      |                 |

<sup>a</sup> All values are means  $\pm$  SD.

<sup>b</sup> Number of individuals in family.

Table 2. Mean serum PBB and DDE concentrations for 24 family units and children.

| Family |               |             | Children |               |            | Aver. age<br>± range |
|--------|---------------|-------------|----------|---------------|------------|----------------------|
| n      | PBB, ppb      | DDE, ppb    | n        | PPB, ppb      | DDE, ppb   |                      |
| 7      | 6.3 ± 5.0     | 5.5 ± 4.0   | 5        | 7.4 ± 6.1     | 3.4 ± 1.4  | 5 ± 4                |
| 6      | 0.9 ± 0.5     | 4.9 ± 4.3   | 3        | 11.8 ± 1.5    | 4.2 ± 1.1  | 7 ± 1                |
| 5      | 26.0 ± 16.    | 4.0 ± 3.0   | 4        | 1.0 ± 0.5     | 3.1 ± 0.6  | 7 ± 3                |
| 6      | 486.0 ± 365.0 | 5.1 ± 3.5   | 3        | 36.7 ± 6.2    | 1.9 ± 0.5  | 6 ± 3                |
| 11     | 48.5 ± 27.2   | 11.3 ± 18.5 | 4        | 388.0 ± 167.5 | 3.1 ± 1.5  | 8 ± 3                |
| 5      | 0.8 ± 3.0     | 8.2 ± 4.7   | 4        | 64.9 ± 28.8   | 2.2 ± 1.0  | 5 ± 2                |
| 7      | 3.6 ± 2.2     | 6.5 ± 4.1   | 3        | 0.6 ± 0.1     | 4.9 ± 0.5  | 11 ± 1               |
| 10     | 1.6 ± 1.0     | 10.6 ± 8.3  | 5        | 4.7 ± 2.4     | 3.5 ± 2.4  | 11 ± 5               |
| 8      | 7.5 ± 3.4     | 9.6 ± 6.2   | 5        | 1.4 ± 0.8     | 5.2 ± 2.2  | 11 ± 7               |
| 5      | 2.9 ± 5.0     | 10.0 ± 11   | 4        | 9.3 ± 3.4     | 4.8 ± 2.0  | 12 ± 4               |
| 6      | 3.9 ± 1.9     | 11.5 ± 4.2  | 3        | 0.8 ± 0.2     | 5.1 ± 0.5  | 12 ± 5               |
| 5      | 5.4 ± 3.0     | 11.1 ± 10.0 | 4        | 4.6 ± 1.9     | 9.7 ± 3.2  | 13 ± 3               |
| 10     | 0.7 ± 0.3     | 8.6 ± 4.4   | 3        | 4.3 ± 2.2     | 4.5 ± 2.5  | 13 ± 2               |
| 5      | 3.2 ± 2.0     | 12.4 ± 13.0 | 6        | 0.6 ± 0.1     | 7.4 ± 3.9  | 14 ± 3               |
| 7      | 2.2 ± 1.5     | 12.9 ± 7.2  | 3        | 2.4 ± 0.6     | 6.1 ± 2.0  | 15 ± 3               |
| 7      | 1.2 ± 0.8     | 9.0 ± 5.3   | 5        | 1.5 ± 0.8     | 9.5 ± 2.4  | 15 ± 8               |
| 4      | 2.1 ± 1.5     | 12.8 ± 11.7 | 5        | 1.1 ± 0.4     | 7.3 ± 5.1  | 16 ± 1               |
| 8      | 3.0 ± 1.1     | 8.2 ± 4.6   | 3        | 1.3 ± 0.4     | 7.1 ± 3.0  | 16 ± 2               |
| 5      | 1.9 ± 1.1     | 12.4 ± 12.0 | 6        | 3.1 ± 1.2     | 5.9 ± 1.8  | 16 ± 5               |
| 5      | 1.3 ± 1.0     | 6.1 ± 4.2   | 3        | 2.1 ± 1.5     | 5.8 ± 1.5  | 17 ± 2               |
| 5      | 1.8 ± 0.6     | 9.8 ± 7.6   | 3        | 1.0 ± 0.4     | 3.1 ± 0.3  | 17 ± 2               |
| 7      | 1.1 ± 0.6     | 9.4 ± 5.7   | 3        | 1.7 ± 0.9     | 4.5 ± 1.0  | 19 ± 3               |
| 5      | 1.8 ± 1.0     | 13.5 ± 7.1  | 4        | 1.4 ± 0.7     | 9.6 ± 1.2  | 20 ± 5               |
| 5      | 2.8 ± 1.3     | 14.3 ± 7.0  | 3        | 2.2 ± 0.6     | 8.9 ± 4.4  | 20 ± 5               |
| 11     | 2.3 ± 2.0     | 8.9 ± 5.5   | 3        | 2.8 ± 1.5     | 12.5 ± 6.6 | 22 ± 4               |
|        |               |             | 6        | 3.0 ± 2.5     | 7.4 ± 1.5  | 22 ± 5               |

Table 3. Range of standard deviation from the mean of average serum PBB and DDE for family units and for children within a family.

| Standard deviation from<br>the mean | Families          |       | Children |       |
|-------------------------------------|-------------------|-------|----------|-------|
|                                     | PBB               | DDE   | PBB      | DDE   |
| Within 30% or 1 ppb                 | 8/24 <sup>a</sup> | 0/24  | 14/24    | 12/24 |
| Within 45% or 1 ppb                 | 10/24             | 1/24  | 18/24    | 17/24 |
| Within 83% (PBB) or<br>70% (DDE)    | 21/24             | 13/24 | 24/24    | 24/24 |
| Within 100%                         | 22/24             | 21/24 |          |       |

<sup>a</sup> All < 1 ppb but > 30%.

Table 4. Peak percentile categories.

| Group                 | PBB serum levels, ppb      |                            |                             |
|-----------------------|----------------------------|----------------------------|-----------------------------|
|                       | Bottom<br>33<br>percentile | Middle<br>33<br>percentile | Highest<br>33<br>percentile |
| Fathers               | 0.2-2.2                    | 2.3-7.8                    | 8.1-1165.3                  |
| Mothers               | 0.01-0.9                   | 0.91-2.8                   | 3.1- 201.0                  |
| Sons, ages 0-12       | 0.01-1.5                   | 1.7-6.2                    | 7.5- 533.0                  |
| Sons, ages 13-18      | 0.05-2.2                   | 2.3-6.8                    | 7.3- 36.5                   |
| Sons, ages 19-35      | 1.0-2.4                    | 2.6-9.6                    | 11.0- 63.0                  |
| Daughters, ages 0-12  | 0.5-1.4                    | 1.5-7.8                    | 8.1- 469.5                  |
| Daughters, ages 13-18 | 0.3-0.9                    | 1.1-2.3                    | 2.7- 19.4                   |
| Daughters, ages 19-35 | 0.01-0.5                   | 0.6-1.2                    | 1.8- 341.4                  |

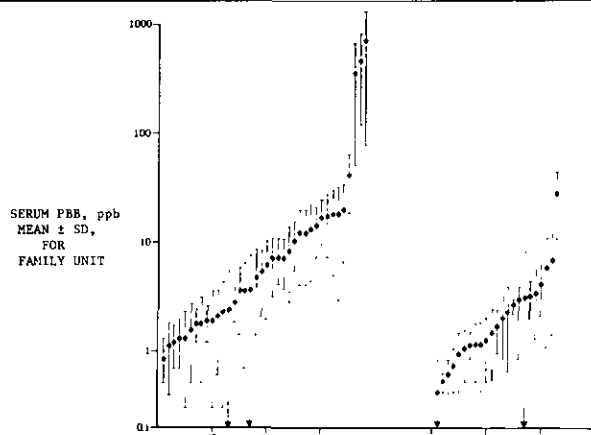


FIGURE 1. Rank order of mean PBB values for (left) 38 quarantined farm family units and (right) 23 nonquarantined farm family units.

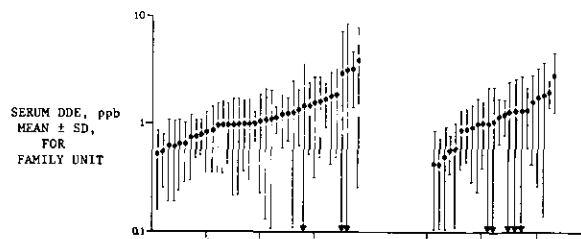


FIGURE 2. Rank order of mean DDE values for (left) 38 quarantined farm family units and (right) 23 nonquarantined farm family units.

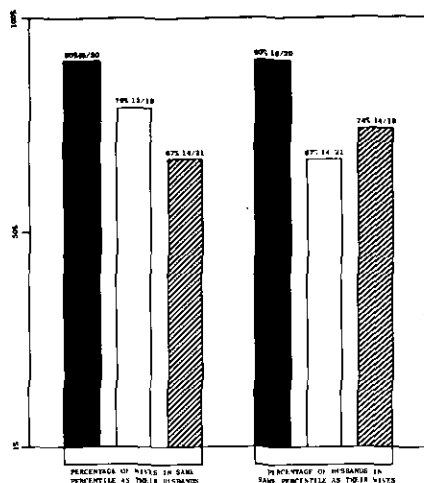


FIGURE 3. Coincidence of serum PBB for wives and husbands within rank percentiles: (■) top (100-66 percentile); (□) middle (66-33 percentile); (▨) bottom (33-0 percentile).

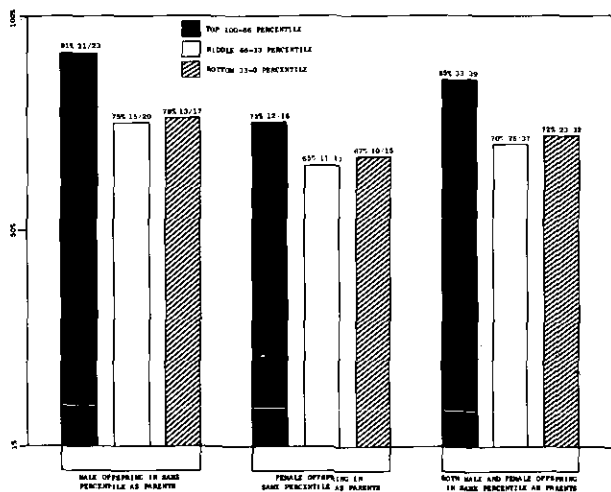


FIGURE 4. Coincidence of serum PBB for parents and offspring.

for the children 12/24 families met this test (Table 3). For PBB, the standard deviations were within 30% or 1 ppb for 8/24 families and 14/24 children subsets. All of the children subsets had SD within 83% of the mean for PBB and within 70% for DDE. These data suggest that family serum PBB cluster, more so than DDE, but that children within a family exhibit clustering of both DDE and PBB.

Family clustering of PBB was further evaluated by rank percentile comparison of individual family members. For this purpose, 60 two-generation, two-parent families of three or more members were ranked according to individual PBB values, and divided into three rank percentiles, for mothers and fathers and for male and female children (Table 4). Offspring were initially ranked in three age sub-

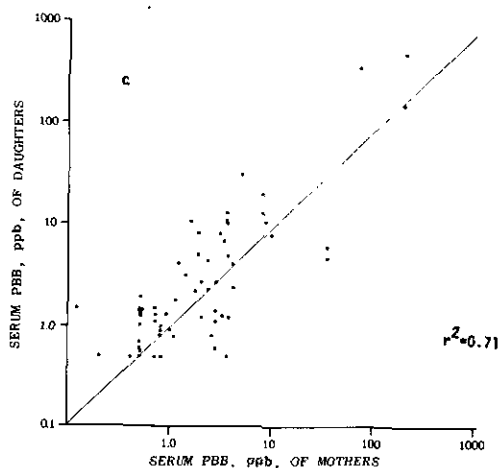
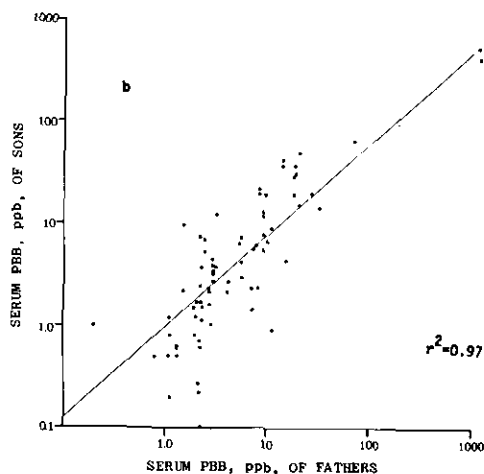
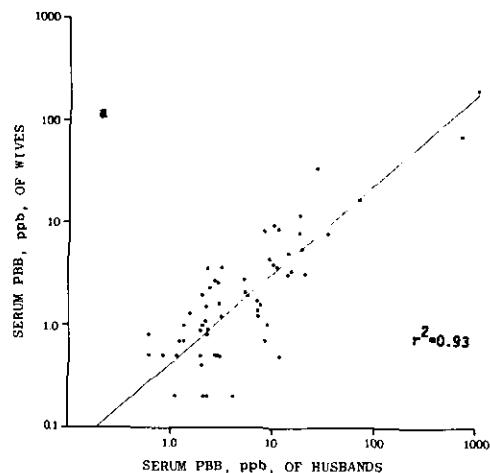


FIGURE 5. Relation of serum PBB for (a) husbands with wives; (b) fathers with sons; (c) mothers with daughters.

groups,  $0 < 12$ ,  $12 < 18$ ,  $18 < 35$  year old and totals within each percentile were summed for all ages. The bar graphs (Figs. 3 and 4) illustrate that parents and children, in every combination studied, had

similar serum PBB rank profiles. The highest prevalence occurred where both parents fell within the top third percentile, 91% of their male children also having serum PBB in the top third percentile.

Family clustering of serum PBB values was demonstrated by comparing intrafamily members. A highly significant linear regression coefficient was observed for husbands versus wives ( $r^2 = 0.93$ ,  $n = 60$ ), sons versus fathers ( $r^2 = 0.97$ ,  $n = 73$ ), and daughters versus mothers ( $r^2 = 0.71$ ,  $n = 64$ ) (Fig. 5). The data are presented logarithmically.

In contrast to the observed correlations of serum PBB values for family members, serum DDE was not similarly correlated. The analogous regression coefficients ( $r^2$ ) for wives versus husbands (0.01), sons versus fathers (0.01), mothers versus daughters (0.34) were nonsignificant except for the last group. Further, the means of mothers and fathers were significantly higher than daughters and sons ( $t = 13.7$  and  $5.3$ , respectively). These results reflect the strong correlations of DDE with age observed for several populations. Indeed, even intrafamily correlations for DDE with age are often significant.

## Discussion

These results suggest that dairy farm families experienced a different intensity and duration of exposure to PBB than to DDE.

In contrast to PBB, serum DDE values within families were correlated only with age and were not related to farm quarantine status. Thus, it is appreciated that serum DDE reflects a long-term, low-level exposure to dietary DDE and DDT residues derived from use of DDT as a pesticide since the 1940's. Serum PBBs tended to fall within a limited range for members of the family. Clustering of serum PBB and DDE occurred for children within a family.

These results suggest varying exposure intensities and durations for PBB and DDE. Although the PBB and DDE were probably both derived from animal food sources, the extent of contamination, onset of exposure and timespan were different for the examined study population of dairy farm families.

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